



US009471525B2

(12) **United States Patent**
Altmann et al.

(10) **Patent No.:** **US 9,471,525 B2**
(45) **Date of Patent:** ***Oct. 18, 2016**

(54) **CABLE WITH CIRCUITRY FOR
COMMUNICATING PERFORMANCE
INFORMATION**

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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

This patent is subject to a terminal dis-
claimer.

(21) Appl. No.: **15/010,166**

(22) Filed: **Jan. 29, 2016**

(65) **Prior Publication Data**

US 2016/0147692 A1 May 26, 2016

Related U.S. Application Data

(63) Continuation of application No. 14/322,753, filed on
Jul. 2, 2014, now Pat. No. 9,274,992.

(60) Provisional application No. 61/856,600, filed on Jul.
19, 2013.

(51) **Int. Cl.**
G06F 3/00 (2006.01)
G06F 13/40 (2006.01)

H04B 11/00 (2006.01)
H04L 5/00 (2006.01)
G06F 13/36 (2006.01)

(52) **U.S. Cl.**
CPC **G06F 13/4022** (2013.01); **G06F 13/36**
(2013.01); **G06F 13/4068** (2013.01); **H04B**
11/00 (2013.01); **H04L 5/00** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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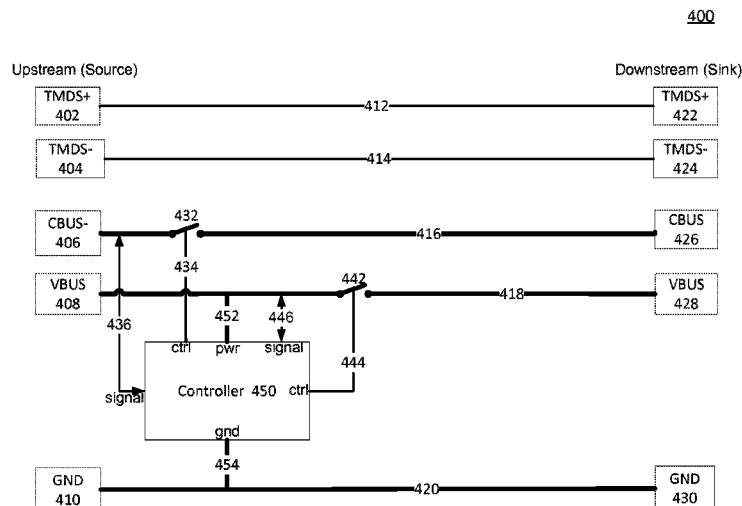
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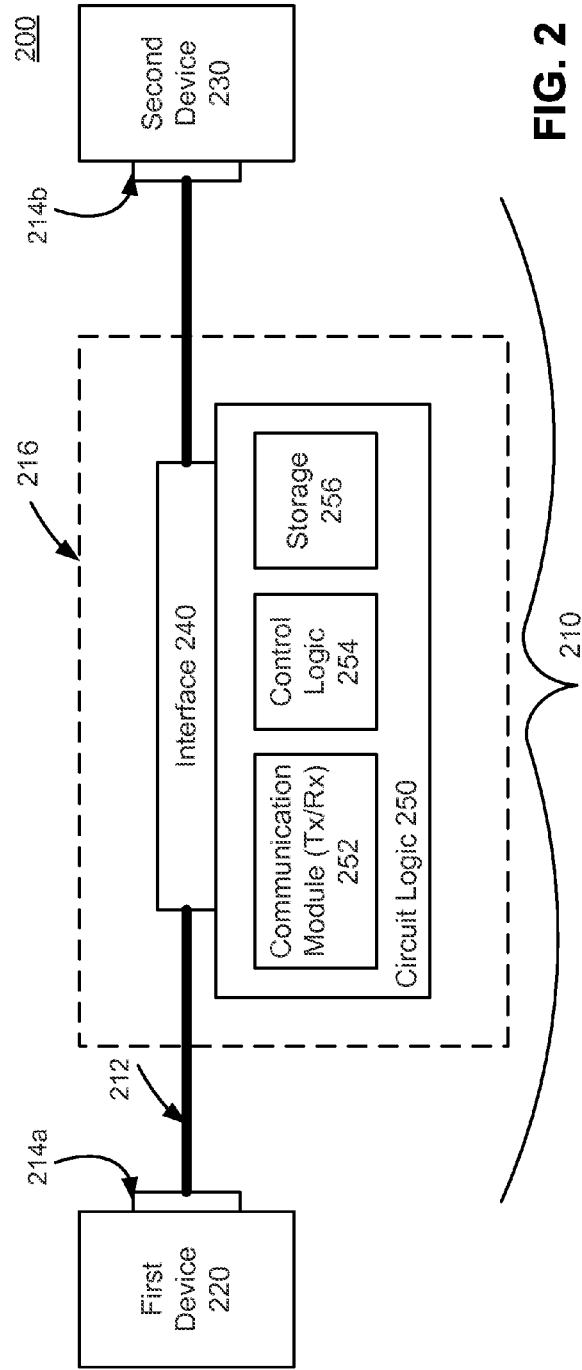
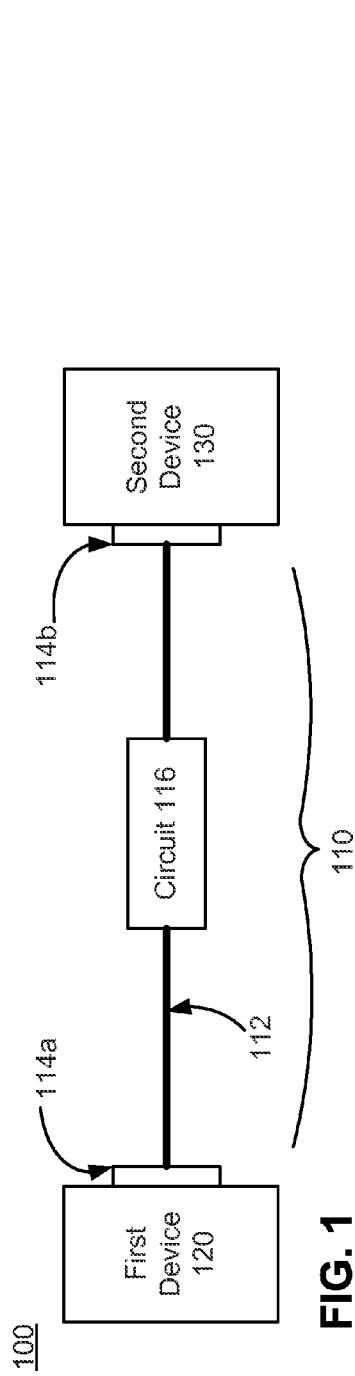
Primary Examiner — David E Martinez

(57) **ABSTRACT**

A cable with circuitry that enables the cable to communicate data in one of at least two different signal modes of operation is presented. In a first signal mode, the cable enables data communication between the circuitry and either a source device or a sink device. The first signal mode can be used either to communicate properties of the cable itself or of a signal passing through the cable to either the source device or the sink device. In a second signal mode, the cable enables data communication between the source device and the sink device. The second signal mode can be used to communicate data in accordance with a predetermined protocol.

19 Claims, 10 Drawing Sheets





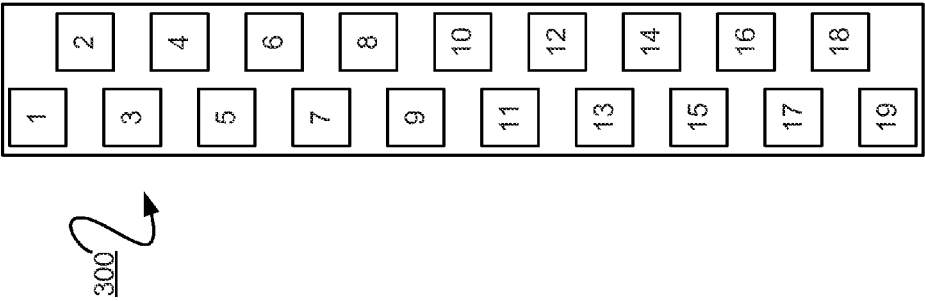


FIG. 3A

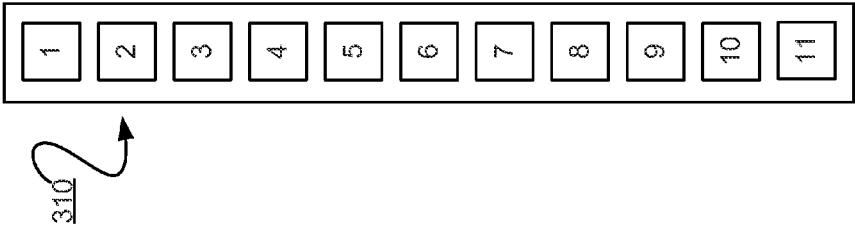


FIG. 3B

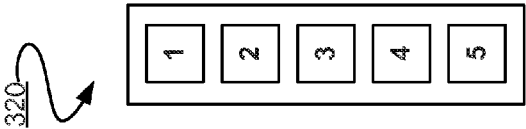


FIG. 3C

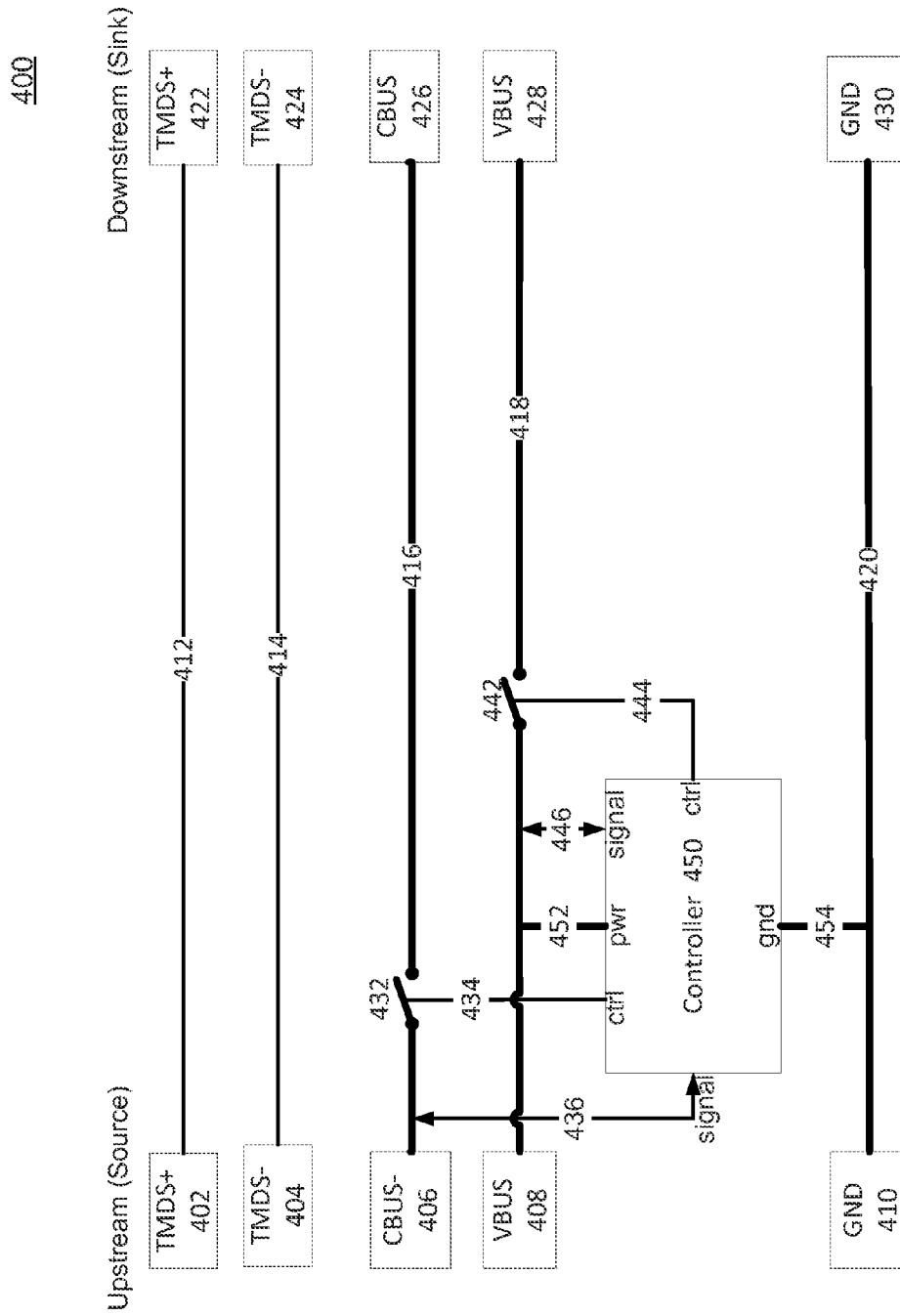


FIG. 4

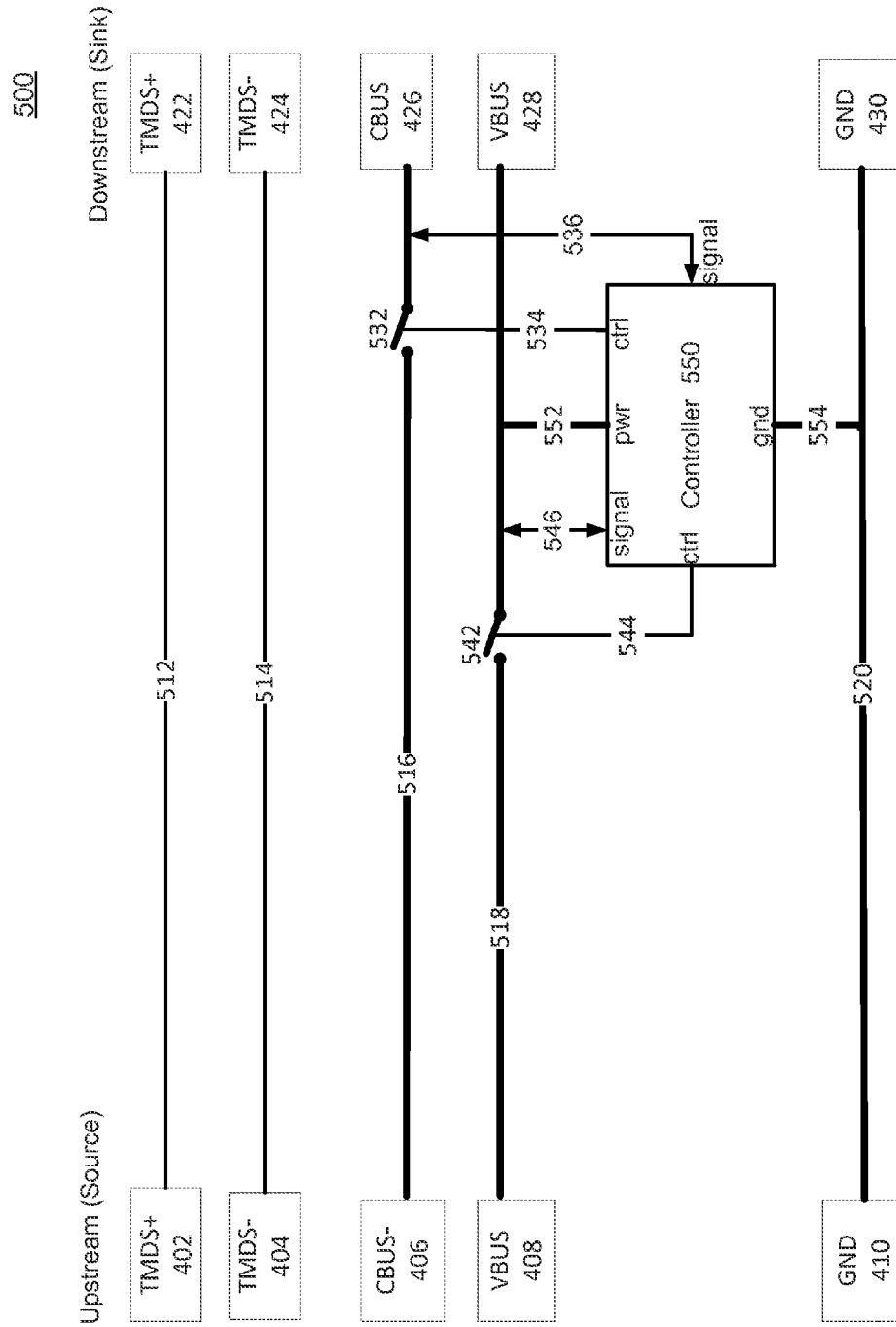
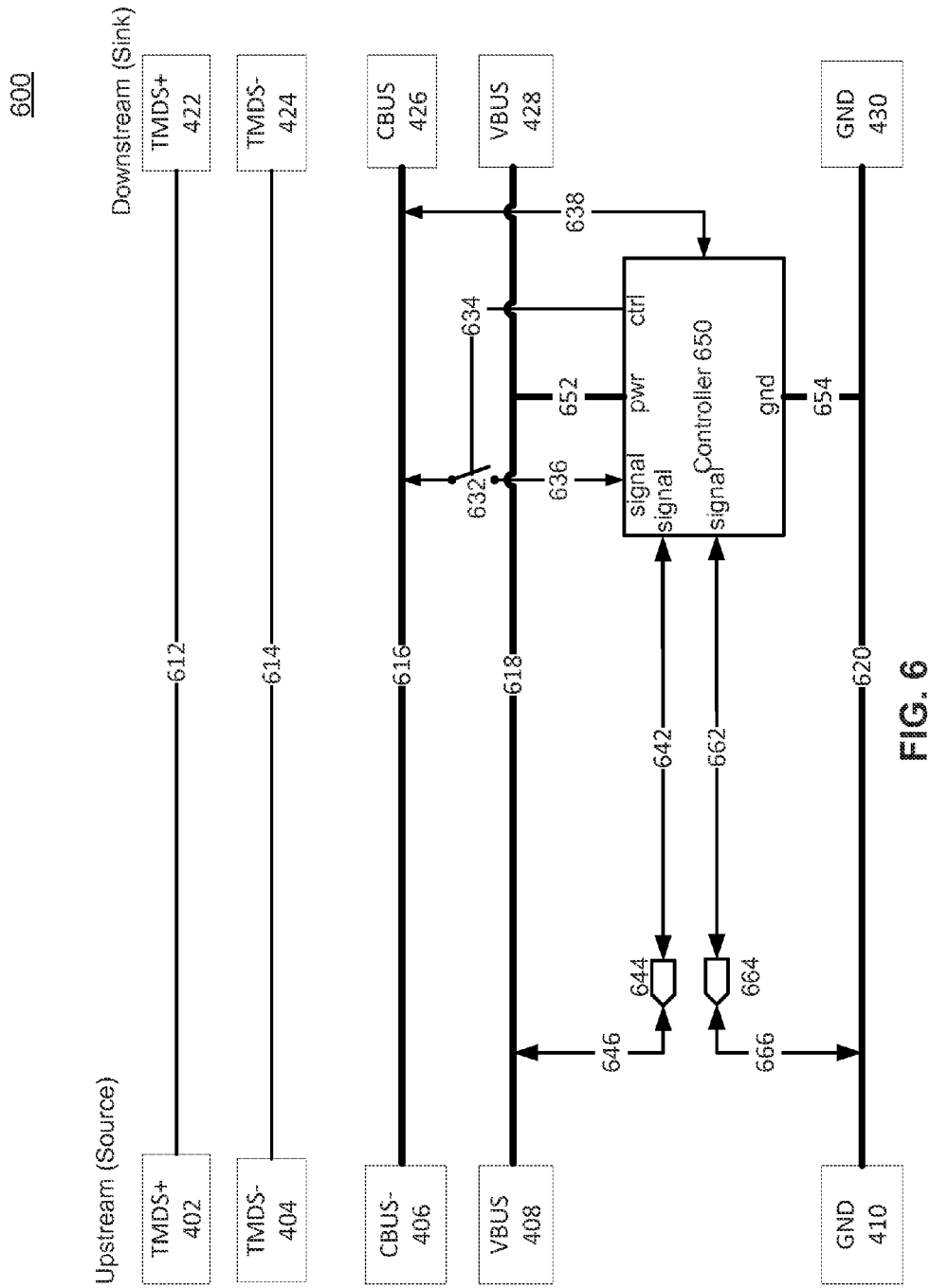


FIG. 5



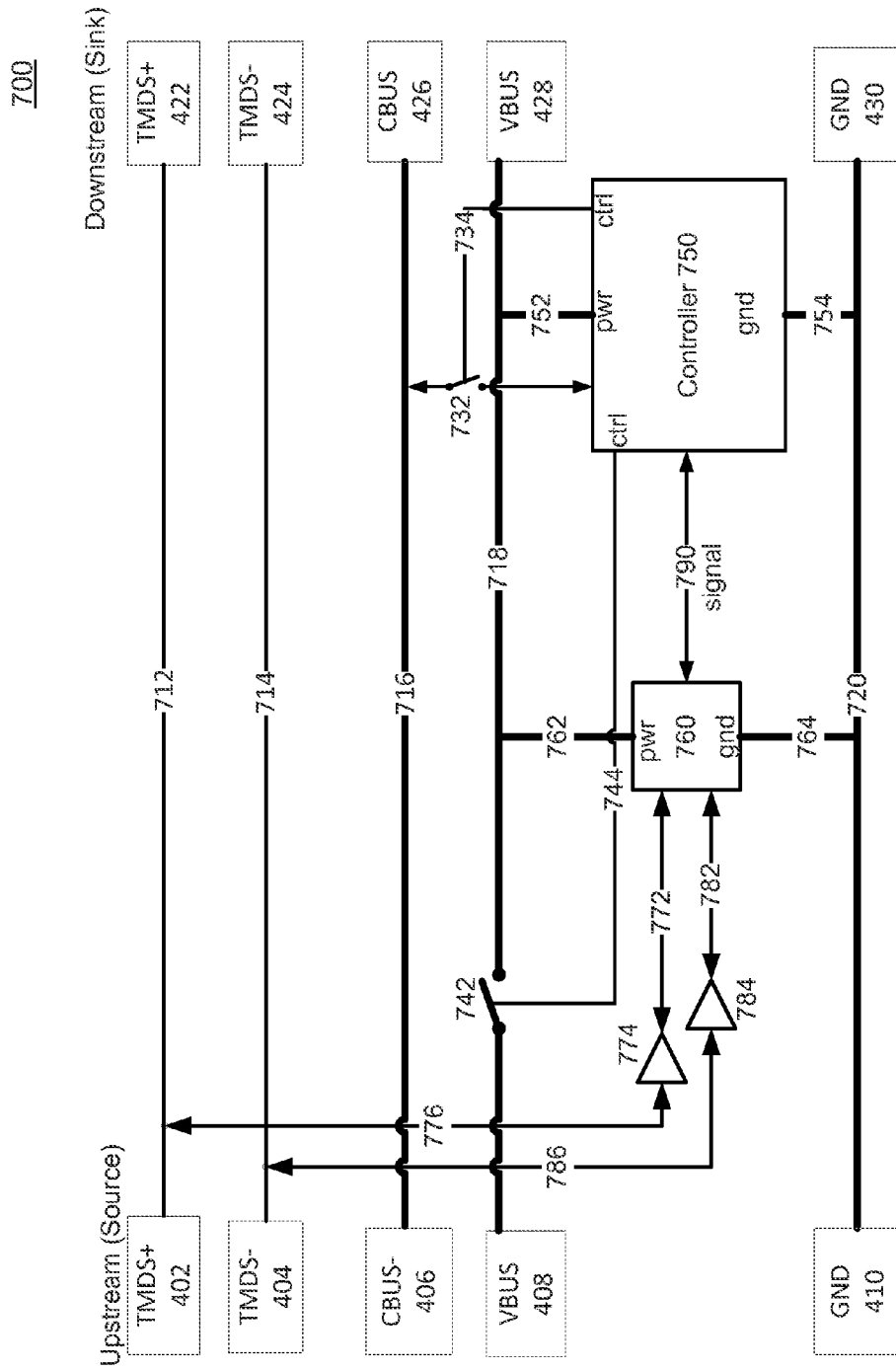


FIG. 7

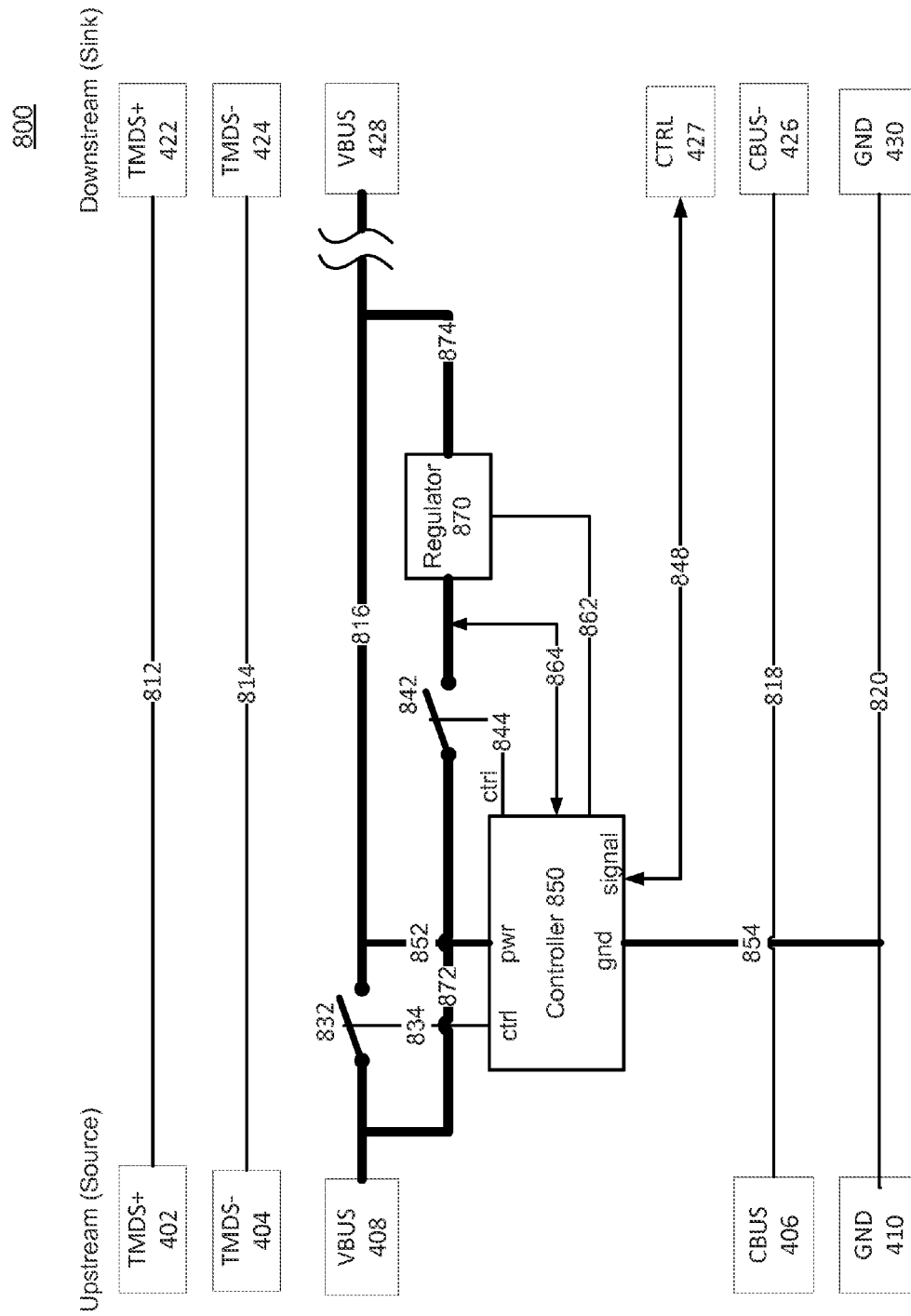


FIG. 8

900

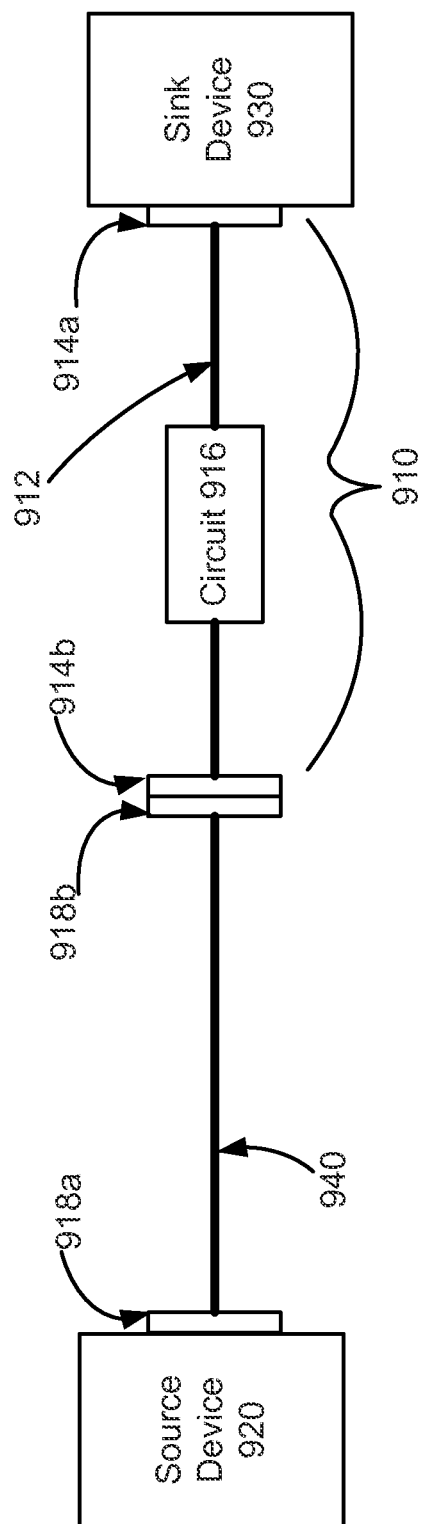
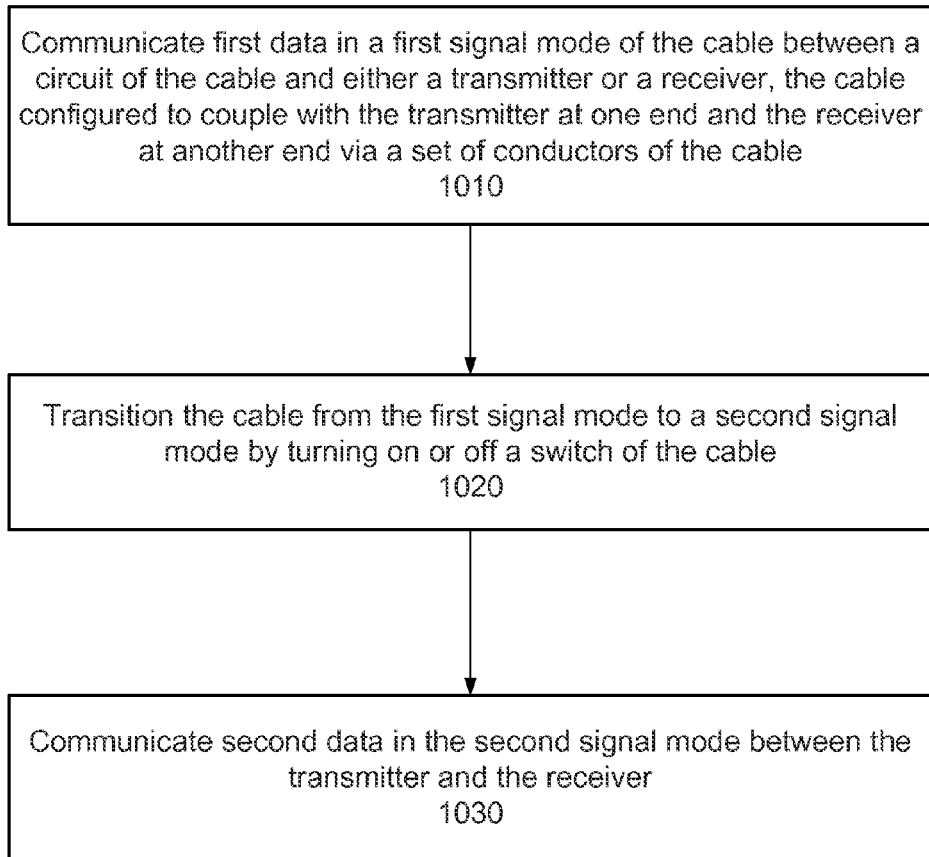


FIG. 9

1000**FIG. 10**

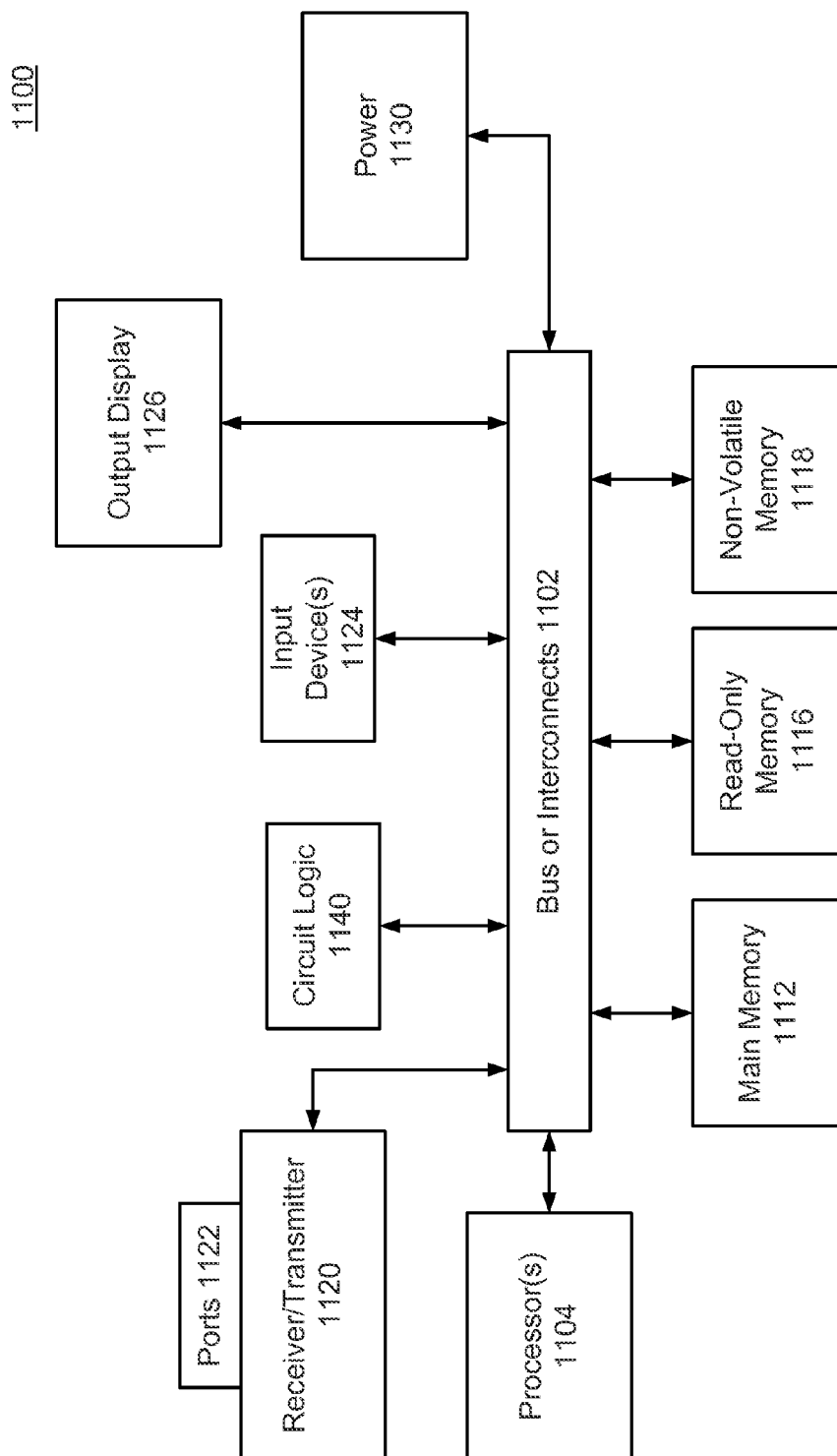


FIG. 11

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CABLE WITH CIRCUITRY FOR COMMUNICATING PERFORMANCE INFORMATION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of patent application Ser. No. 14/322,753, filed on Jul. 2, 2014 which claims priority to a provisional U.S. patent application No. 61/856,600, filed on Jul. 19, 2013, which are incorporated by reference herein in their entirety.

BACKGROUND

1. Field of the Disclosure

This disclosure pertains in general to a cable for communicating data between a transmitter and a receiver, and more particularly to a cable that includes circuitry for communicating performance information with either the transmitter or the receiver.

2. Description of the Related Art

Video and audio data is typically transferred from one device to another across using communication links (e.g., wired or wireless links) with protocols such as high definition multimedia interface (HDMI) or mobile high-definition link (MHL). Wired communication links can include cables comprising one or more conductors for communicating data between devices. Cables used for the wired communication links are selected based on, among other features, a power handling capability (at both a source end and sink end of the cable).

While some interface standards can provide a mechanism for the cable between a source device and a sink device to identify itself as being a compliant device for that interconnect (e.g. MHL), there are no current solutions for an interconnect to indicate to another device—either a source device or a sink device—whether a performance parameter of the interconnect is within a performance range of that interface standard. For example, if an interface standard allows a sink to provide 5 Volts at up to 1 Ampere to a connected source, then the cable is expected to be able to electrically handle signals up to 5 Watts. A cable with a power handling capacity of less than 5 Watt would not be able to support such standard and would not be able to indicate its inability to a coupled device because it lacks any such means to indicate such limitation to the coupled device.

Cable length, for example, can be a marketable feature. The longer the length of a cable the more difficult for the cable to maintain the quality of signals being carried through the cable. Therefore, to be able to use longer cables effectively, there is a need for a mechanism through which a cable can identify itself to and/or indicate to a coupled device that the cable has one or more limitations with respect to performance requirements as required by a particular interface standard.

SUMMARY

Embodiments of the present disclosure relate to a cable that includes circuitry for communicating performance information with either the transmitter or the receiver. The cable is coupled between a transmitter and a receiver for multimedia communications. The cable includes a set of conductors extending from one end of the cable to couple with the transmitter to Another end of the cable to couple with the receiver and a switch coupled to at least one of the

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set of conductors. The cable also includes a circuit coupled to the switch and configured to control the switch to transition the cable from a first signal mode to a second signal mode, a path established via the set of conductors in the first signal mode to communicate first data between the circuit and either the transmitter or the receiver, and another path established via the set of conductors in the second signal mode to communicate second data between the transmitter and the receiver.

In one embodiment, the cable's circuit controls the switch to transition the cable from the second signal mode to the first signal mode.

In one embodiment, the cable can be transitioned from the first signal mode to the second signal mode at a predetermined time interval.

In one embodiment, the cable can be transitioned from the second signal mode to the first signal mode at a predetermined time interval.

In one embodiment, the switch is controlled by either the receiver or the transmitter.

In one embodiment, the circuit may cause the switch to disconnect at least one of the set of conductors between the transmitter and the receiver in the first signal mode.

In one embodiment, the circuit causes the switch to couple at least one of the set of conductors with the circuit in the first signal mode.

In one embodiment, the first data includes information derived from a measurement of at least one property of a signal passing through the set of conductors.

In one embodiment, information derived from a measurement of at least one property of the signal passing through the set of conductors includes at least one of: voltage level, current level, power of the signal, frequency components of the signal, attenuation components of the signal, and a degree of skewing of the signal.

In one embodiment, the first data includes information associated with at least one characteristic of the cable, the at least one characteristic of the cable including at least one of: impedance, length, operable frequency range, measured degree of crosstalk between the set of conductors, electromagnetic interference, and common-mode radiation.

In one embodiment, the first data can be stored in a memory of the circuit during manufacturing of the cable.

In one embodiment, the cable includes a voltage regulator configured to convert a voltage level of a signal carrying the second data from a first voltage level to a second voltage level.

In one embodiment, the end of the cable coupled to either the transmitter or the receiver is further configured to couple with the transmitter or the receiver through a coupling with a second cable.

Embodiments also relate to a method of communicating data between a transmitter of a first device and a receiver of a second device over a cable. The first data is communicated in a first signal mode of the cable between a circuit of the cable and either the transmitter or the receiver, the cable configured to couple with the transmitter at one end and the receiver at another end via a set of conductors of the cable. The cable transitions from the first signal mode to a second signal mode by turning on or off a switch of the cable and communicating second data in the second signal mode between the transmitter and the receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

The teachings of the embodiments disclosed herein can be readily understood by considering the following detailed description in conjunction with the accompanying drawings.

FIG. 1 is a high-level block diagram of a system for multimedia data communications, according to one embodiment.

FIG. 2 is a block diagram of a cable, according to one embodiment.

FIG. 3A is a diagram illustrating a pinout of a high definition multimedia interface connector, according to one embodiment.

FIG. 3B is a diagram illustrating a pinout of a mobile high-definition link (MHL) connector, according to one embodiment.

FIG. 3C is a diagram illustrating of a pinout of a 5-pin MHL connector, according to one embodiment.

FIG. 4 is a block diagram depicting a cable comprising circuitry on the source end of the cable to configure the cable to communicate between the circuitry and a source device, according to one embodiment.

FIG. 5 is a block diagram depicting a cable comprising circuitry on the sink end of the cable to configure the cable to communicate between the circuitry and a sink device, according to one embodiment.

FIG. 6 is a block diagram depicting a cable comprising circuitry configured to couple to a conductor of the cable, according to one embodiment.

FIG. 7 is a block diagram depicting a cable comprising circuitry configured to measure a property of a signal passing through the cable, according to one embodiment.

FIG. 8 is a block diagram depicting a cable comprising circuitry comprising a voltage regulator, according to one embodiment.

FIG. 9 is a block diagram depicting a system for connecting a source device with a sink device using two cables, according to one embodiment.

FIG. 10 is a flowchart depicting a method for communicating data between a source device and a sink device over a cable, according to one embodiment.

FIG. 11 is a block diagram of a source device or a sink device that communicates data over a cable, according to one embodiment.

DETAILED DESCRIPTION

The Figures (FIGS.) and the following description relate to various embodiments by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles discussed herein. Reference will now be made in detail to several embodiments, examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality.

Embodiments of the present disclosure relate to a cable with circuitry that enables the cable to communicate data in one of at least two different signal modes of operation. In a first signal mode, the cable enables data communication between the circuitry and either a source device or a sink device. The first signal mode can be used either to communicate properties of the cable itself or of a signal passing through the cable to either the source device or the sink device. In a second signal mode, the cable enables data communication between the source device and the sink device. The second signal mode can be used to communicate data in accordance with a predetermined protocol.

As used in this disclosure, the term “source device” refers to a device that provides data stream to another device (e.g.,

a sink device). Correspondingly, the term “sink device” described herein refers to a device that receives data stream from another device (e.g., a source device). Examples of source device and sink device include mobile phones, smart phones, Blu-ray players, gaming consoles, laptop computers, tablet computers, televisions, and display devices. In some embodiments, source device can be a portable device typically powered by a battery whereas a sink device can be a device that is typically not portable and typically powered by an alternating current (AC) source. Alternatively, source device and/or sink device can be repeater devices.

The term “transmitter” described herein refers to a device or a component of a device that transmits a signal, which can be received by a receiving device or a component of a receiving device. Correspondingly, the term “receiver” described herein refers to a device or a component of a device that receives a signal transmitted by a transmitting device or a component of a transmitting device. In some embodiments, a transmitter or a receiver can be embedded in source and sink devices. Alternatively, a transmitter and a receiver can be embedded in each of the source and sink devices.

FIG. 1 is a high-level block diagram of a system 100 for multimedia data communications, according to one embodiment. System 100 can include, among other components, first device 120, second device 130, and cable 110 between first device 120 and second device 130. First device 120 may function as a source device that can transmit multimedia data to second device 130 that may function as a sink device. Alternatively, first device 120 can function as a sink device and second device 130 can function as a source device.

Cable 110 includes circuit 116 that can configure cable 110 to communicate data between circuit 116 and either first device 120 or second device 130. One advantage of data communication between circuit 116 and either first device 120 or second device 130 is an ability to communicate properties of cable 110 itself or of a signal passing through cable 110 to either first device 120 or second device 130. For example, circuit 116 can provide impedance information of a conductor of cable 110 to either first device 120 or second device 130 for further processing. Similarly, circuit 116 can measure voltage drop across the length of cable 110 and provide that information to a sink device (e.g., second device 130), which can adjust the voltage provided to cable 110 accordingly. In other words, circuit 116 of cable 110 can provide real-time information of either a property of cable 110 itself or of a signal passing through cable 110 to one of the devices coupled to cable 110 and such information can be used to adjust the data communicated over cable 110.

First device 120 and second device 130 can include a transmitter (not shown) and/or a receiver (not shown) to variously implement communications between first device 120 and second device 130 via cable 110. Cable 110 includes connectors 114a and 114b at either ends of cable 110 to couple with first device 120 and second device 130. One or both connectors 114a and 114b include one or more contacts, such as pins, balls, pads, and/or other connection hardware, the configuration of which is compatible with a particular interface standard. For example, connector 114a (and/or 114b) can be a micro-USB, mini-USB, or standard USB connector with USB 2.0, USB 3.0, or other USB standard. Alternatively, connector 114a (and/or 114b) is compatible with one or more of: an HDMI standard such as the HDMI 1.4 standard released May 28, 2009, by HDMI Licensing, LLC of Sunnyvale, Calif.; an MHL standard such as the MHL 1.0 specification released Jun. 30, 2010, by the MHL Consortium of Sunnyvale, Calif.; a Digital Visual

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Interface (DVI) standard such as the DVI 1.0 standard released Apr. 2, 1999, by the Digital Display Working Group of Vancouver, Wash.; and a DisplayPort standard such as the DisplayPort 1.2 standard released Dec. 22, 2009, by the Video Electronics Standards Association of Newark, Calif.

Cable **110** includes a set of conductors (e.g., conductor set **112**) coupled between connectors **114a** and **114b**, and circuit **116** for communicating data between first device **120** and second device **130**. Conductor set **112** includes one or more conductors for variously providing power (e.g., to exchange a supply voltage and a ground voltage) and signals (e.g., data, clock and/or control signals) between first device **120** and second device **130**. Circuit **116** is operable to detect the presence of a device capable of receiving or transmitting data between first device **120** and second device **130**, as described below in detail with reference to FIGS. **4** through **9**.

FIG. **2** is a block diagram depicting some of the elements of circuit **216**, which is similar to FIG. **1**'s circuit **116**. Circuit **216** is part of cable **210** coupling first device **220** and second device **230** via connectors **214a** and **214b**. Cable **210** includes a set of conductors (e.g., conductor set **212**) and circuit **216**. Circuit **216** includes interface **240** and circuit logic **250**. Interface **240** is used to exchange signals between one or more conductors of conductor set **212** and circuit logic **250**. Circuit logic **250** can include, among other components, communication module **252**, control logic **254**, and storage **256**.

Communication module **252** includes a transmit module (not shown) or a receive module (not shown). Alternatively, communication module **252** can include both a transmit module and a receive module. A transmit module transmits signals whereas receive module receives signals that are transmitted. Communication module **252** is configured by control logic **254** to either transmit data or receive data. Alternatively, control logic **254** can be configured to both transmit data and receive data. Control logic **254** can also configure conductor set **212** to operate cable **210** in a plurality of modes of operation. For example, a first signal mode of operation can be between circuit **216** and either first device **220** or second device **230**. And a second signal mode of operation can be a direct communication between first device **220** and second device **230**. As will be described below in detail with reference to FIGS. **4** through **9**, control logic **254** can control switches (not shown) to configure cable **210** in either the first signal mode or the second signal mode of operation.

Circuit **216** can communicate relevant information to an external device (e.g., first device **220** or second device **230**) to identify cable **210** to the external device as having interface hardware compatible with an interface standard. Alternatively, circuit **216** can identify a performance limitation of cable **210** and indicate such performance limitation to an external device. For example, circuit **216** can directly or indirectly indicate to first device **220** (and/or second device **230**) that an operation of cable **210** is constrained by a performance threshold or a performance range (e.g., related to operable range of power, voltage, current, frequency or the like), which is different than a corresponding threshold or range specified by the interface standard.

Storage **256** is a memory to store information indicative of one or more performance characteristics of the cable. Storage **256** can be a random access memory (RAM) or other dynamic storage memory device for storing dynamic information. Alternatively, storage **256** can comprise a read only memory (ROM) or other non-volatile static storage device (e.g., flash memory, a hard disk, solid-state drive) for

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storing static information. In an embodiment, storage **256** can store information related to characteristics of cable **210** such as impedance, length, operable frequency range, measured degree of crosstalk between the set of conductors, electromagnetic interference, and common-mode radiation. Such cable characteristic information can be stored in storage **256** when cable **210** is manufactured. Alternatively, such cable characteristic information can be stored in storage **256** in real-time while cable **210** is being used to communicate data.

FIGS. **3A** through **3C** are block diagrams depicting pinouts **310** and **320** of a connector in accordance with interface standards HDMI and MEL respectively. Pinout **330** is a MHL-based 5-pin implementation. Pinout **310** of FIG. **3A** depicts an HDMI connector comprising nineteen pins, including three pairs of differential data signal pins. In an exemplary embodiment, the three pairs of differential data signal pins can be mapped as follows: TMDS DO+ and TMDS DO- mapped to pins 7 and 9; TMDS D1+ and TMDS D1- mapped to pins 4 and 6; and TMDS D2+ and TMDS D2- mapped to pins 1 and 3. Pinout **310** also includes a pair of pins carrying clock signals, TMDS Clock+ and TMDS Clock-, which can be mapped to pins 10 and 12. Pinout **310** further includes a power supply pin (+5V power supply from transmitter) that can be mapped to pin 18 and a ground pin that can be mapped to pin 17. The remaining pins of pinout **310** include data shield, clock shield, and other control pins. A complete description of each HDMI connector pin and its mapping can be found in the HDMI 1.4 standard released May 28, 2009, by HDMI Licensing, LLC of Sunnyvale, Calif., which is incorporated by reference herein in its entirety.

Pinout **320** of FIG. **3B** depicts an MHL connector comprising eleven pins, including two pairs of differential data signal pins. In an exemplary embodiment, the two pairs of differential data signal pins can be mapped as follows: TMDS Data+ and TMDS Data- mapped to pins 1 and 3; and USB Data+ and USB Data- mapped to pins 8 and 9. Pinout **320** also includes a pair of pins carrying clock signals, TMDS Clock+ and TMDS Clock-, which can be mapped to pins 6 and 8. Pinout **320** further includes a power supply pin (+5V power supply from receiver) that can be mapped to pin 11 and a ground pin that can be mapped to pin 11. The remaining pins of pinout **320** include TMDS data shield, TMDS clock shield, and control bus. A complete description of each MHL connector pin and its mapping can be found in the MHL standard such as the MHL 1.0 specification released Jun. 30, 2010, which is incorporated by reference herein in its entirety.

Pinout **330** of FIG. **3C** depicts a 5-pin MHL connector comprising five pins, including one pair of differential data signal pins mapped as follows: TMDS+ and TMDS- mapped to pins 2 and 3. Pinout **330** also includes a power supply pin (+5V VBUS) that is mapped to pin 1, a ground pin that is mapped to pin 5, and a control bus pin mapped to pin 4. A complete description of each pin of the 5-pin MHL connector its mapping can be found in the MHL standard such as the MHL 1.0 specification released Jun. 30, 2010.

FIGS. **4** through **9** depict cables connected between a source device and a sink device for communicating data. While FIGS. **4-9** depict MHL connectors with five pins (e.g., TMDS+ **402**, TMDS- **404**, CBUS- **406**, VBUS **408**, and GND **410** of FIG. **4**), it will be understood that the disclosure of FIGS. **4** through **9** is not limited to 5-pin MEL connectors but also extends to others connectors (e.g., HDMI or MHL) with any number of pins such as connectors including pins

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representing a combination of data pins, a control pin, a power supply pin, and a ground pin. For example, FIGS. 4 through 9 can include HDMI connectors with nineteen pins each or MHL connectors with eleven pins each. For each of the following embodiments depicted in FIGS. 4 through 9, the source end (or upstream end) of a cable is on the left hand side of the figure and the sink end (or downstream end) of the cable is on the right hand side of the figure. This disclosure is not limited to any particular standard and it is applicable to any audio/video interface standard (e.g., HDMI or MHL) or any audio/video proprietary interfaces that enable communication of data over a cable.

FIG. 4 is a block diagram depicting cable 400 comprising circuitry on the source end of cable 400 to configure the cable to communicate between the circuitry and a source device, according to one embodiment. The circuitry can configure cable 400 in a mode of operation where the circuitry can communicate information (transmit and/or receive) with an external device on the source end. The mode of operation is established by turning off a switch and thereby disconnecting a connection between the source end and the sink end of cable 400.

In FIG. 4, the source end of cable 400 is connected with a connector (not shown) that includes pins, TMDS+ 402, TMDS- 404, CBUS- 406, VBUS 408, and GND 410. The sink end of cable 400 is connected with a connector (not shown) that includes pins, TMDS+ 422, TMDS- 424, CBUS 426, VBUS 428, and GND 430. Cable 400 communicates data from the source end of cable 400 to the sink end of cable 400. For example, cable 400 can be connected to a mobile phone at the source end and to a high-definition television at the sink end such that a user of the mobile phone can transmit data to the television to display a video being played on the mobile phone.

Cable 400 includes a set of conductors (i.e., conductors 412, 414, 416, 418, and 420) between each pin of a connector on the source end and the sink end. Each conductor of the set of conductors is used for transmitting data from the source device to the sink device through the connectors at either end. Cable 400 also includes a circuit that comprises controller 450 and switches 432 and 442.

Switch 432 is a three-point switch between CBUS- pin 406, CBUS pin 426, and controller 450. Switch 432 can be configured to form a connection either between CBUS- pin 406 and CBUS pin 426 or between CBUS- pin 406 and controller 450 through signal 436. When switch 432 forms a connection between CBUS- pin 406 and CBUS pin 426, signal path 436 is placed in a high impedance state (e.g., by placing an additional switch (not shown) in series with signal path 436 in off state) so as to not affect the operation of controller 450 due to the external devices (i.e., source or sink devices). Similarly, when switch 432 forms a connection between CBUS- pin 406 and controller 450 through signal path 436, signal path 416 is placed in a high impedance state (e.g., by placing switch 432 in off state) so as to not affect the performance of controller 450 or the source device due to the sink device.

Switch 442, similar to switch 432, is a three-point switch between VBUS pin 408, VBUS pin 428, and controller 450. That is, switch 442 can be configured to form a connection either between VBUS pin 408 and VBUS pin 428 or between VBUS pin 408 and controller 450 through signal 446. When switch 442 forms a connection between VBUS pin 408 and VBUS pin 428, the signal path 446 is placed in a high impedance state (e.g., by placing an additional switch (not shown) in series with signal path 446 in off state) so as to not affect the performance of controller 450 due to the

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external devices (i.e., source or sink devices). Similarly, when switch 442 form a connection between VBUS pin 408 and controller 450, the signal path depicted by 418 is placed in a high impedance state (e.g., by placing switch 442 in off state) so as to not affect the performance of controller 450 or the source device due to the sink device.

Controller 450 controls switches 432 and 442 to place cable 400 in one of at least two signal modes of operation. In a first signal mode of operation, communication of data between controller 450 and an external device connected to cable 400 (i.e., either a source device or a sink device) is enabled. The first signal mode can be used by a source device to read characteristic data of cable 400 from a memory (e.g., storage 256) of controller 450 or write cable characteristic data to the memory. For example, cable characteristic data can include data associated with at least one of the following characteristics of the conductor set: impedance of the set of conductors, length of a cable, operable frequency range of the cable, measured degree of crosstalk between the set of conductors, electromagnetic interference, and common-mode radiation. Cable 400 is placed in the first signal mode by having controller 450 turning off either switch 432 and establishing a signal path with CBUS- pin 406 (i.e., source device), or turning off switch 442 and establishing a signal path with VBUS pin 408 (i.e., source device). Alternatively, both switches 432 and 442 can be turned off and both signal paths between CBUS- pin 406 and signal 436, and between VBUS pin 408 and signal 446 can be established.

A second signal mode of operation enables communication of data between a source device and a sink device connected to cable 400. The second signal mode can be used for communication of data in a normal protocol mode. For example, a cable can communicate data using Transition Minimized Differential Sampling (TMDS). Cable 400 is placed in the second signal mode by having controller 450 turn on switch 432 to establish a signal path between CBUS- pin 406 (i.e., source device) and CBUS pin 426 (i.e., sink device), and turn on switch 442 to establish a signal path between VBUS pin 408 (i.e., source device) and VBUS pin 428 (i.e., sink device).

In one embodiment, the first signal mode can be set as default mode of operation for cable 400. That is, when a cable is shipped from the factory, controller 450 is configured to operate cable 400 in the first signal mode. In this way, cable 400 is able to, for example, measure a signal property and communicate to an external device (i.e., source or sink device) by default. Alternatively, the second signal mode can be set as the default mode of operation.

Controller 450 is powered by a power supply signal and a ground signal carried by conductors 418 and 420, which are represented by power signal 452 and ground signal 454, respectively. Power and ground signals for controller 450 are connected to the source end of cable 400 such that even when switches 432 and 442 are turned off (and consequently power and ground signals are cutoff from the sink device), controller 450 can still receive power from the source device.

FIG. 5 is a block diagram depicting cable 500 comprising circuitry on the sink end of cable 500 to configure the cable to communicate between the circuitry and a sink device, according to one embodiment. The circuitry can configure cable 500 in a mode of operation where the circuitry can communicate information (transmit and/or receive) with an external device on the sink end. The mode of operation is established by turning off a switch (e.g., switch 532) and

thereby disconnecting a connection between the source end and the sink end of cable 500.

In FIG. 5, the source end of cable 500 is connected with a connector (not shown) that includes pins, TMDS+ 402, TMDS- 404, CBUS- 406, VBUS 408, and GND 410. The sink end of cable 500 is connected with a connector (not shown) that includes pins, TMDS+ 422, TMDS- 424, CBUS 426, VBUS 428, and GND 430. The pins on the source end and the sink end of cable 500 are the same as the pins of cable 400 described above with reference to FIG. 4.

Cable 500 includes a set of conductors (i.e., conductors 512, 514, 516, 518, and 520) between each pin of a connector on the source end and the sink end. Each conductor of the set of conductors is used for transmitting data from the source device to the sink device through the connectors at either end. Cable 500 also includes a circuit that comprises controller 550, and switches 532 and 542. Cable 500 is similar to cable 400 described above except that controller 450 is placed on the source end of cable 400 whereas controller 550 is placed at the sink end of cable 500.

Controller 550 is powered by a power supply signal and a ground signal carried by conductors 518 and 520, and are represented by power signal 552 and ground signal 554, respectively. Power and ground signals for controller 550 are connected to the sink end of cable 500 such that even when switches 532 and 542 are turned off (and consequently power and ground signals are cutoff from the source device), controller 550 can still receive power from the sink device. The functionality of controller 550 and its controlling of switches 532 and 542 is similar to controller 450 and its controlling of switches 432 and 442 described above with reference to FIG. 4. The functionality and operation of signal path 536 is similar to that of signal path 436 described above with reference to FIG. 4 except that signal path 436 connects to the source end of the cable whereas signal path 536 connects to the sink end (thereby can be controlled by the sink device) of the cable. In an exemplary embodiment when a user of a smart phone wants to stream a video playing on his smart phone on to a high-definition television through cable 500, the smart phone is the source device and the television is the sink device. In addition to displaying a video stream from the smart phone on the television (e.g., using conductors 512 and 514), the smart phone's battery can also be charged using the power supply from the television (e.g., using conductor 518).

FIG. 6 is a block diagram depicting cable 600 (e.g., a cable) comprising circuitry coupling to a conductor of cable 600, according to one embodiment. The circuitry can configure cable 600 in a mode of operation where the circuitry can measure a property of cable 600 and communicate the measured information with an external device on either the source end or the sink end. The mode of operation is established by turning on a switch to form a coupling between the circuitry and the conductor without disconnecting a connection between the source end and the sink end of cable 600.

In FIG. 6, the source end of cable 600 is connected with a connector (not shown) that includes pins, TMDS+ 402, TMDS- 404, CBUS- 406, VBUS 408, and GND 410. The sink end of cable 600 is connected with a connector (not shown) that includes pins, TMDS+ 422, TMDS- 424, CBUS 426, VBUS 428, and GND 430. The pins on the source end and the sink end of cable 600 are the same as the pins of cable 400 described above with reference to FIG. 4. Cable 600 includes a set of conductors (i.e., conductors 612, 614, 616, 618, and 620) between each pin of a connector on the source end and the sink end. Each conductor of the set

of conductors is used for transmitting data from the source device to the sink device through the connectors at either end. Cable 600 also includes a circuit that comprises controller 650, switch 632, and signal paths between controller 650 and one or more of conductors of the set of conductors.

Switch 632 is connected between conductor 616 (connecting CBUS- pin 406 on source end and CBUS pin 426 on sink end) and controller 650. By turning on switch 632, a connection between conductor 616 and controller 450 through signal path 636 is established. Controller 650 controls switch 632 using control signal 634. When controller 650 turns off switch 632, signal path 636 is placed in a high impedance state so as to not affect the performance of controller 650 due to the external devices (i.e., source or sink devices). On the other hand, when controller 650 turns on switch 632, controller 650 can communicate with either the source device (e.g., via conductor 616 and CBUS- pin 406) or sink device (e.g., via conductor 616 and CBUS pin 426). Controller 650 turns on switch 632 in a signal mode where the source and sink devices are not communicating data between themselves (e.g., first signal mode). Because conductor 616 is not being used by the source and sink devices in the signal mode where the source and sink devices are not communicating data between themselves, controller 650 can communicate with either of the source or sink devices. FIG. 6 further depicts signal path 638 connected between CBUS pin 426 and controller 650 such that controller 650 can be controlled by a sink device even when switch 632 is turned off. In some embodiments, cable 600 does not include signal path 638 and controller 650 can be controlled by a sink device through signal path 636 when switch 632 is turned on.

FIG. 6 also depicts two sets of signal paths between conductors and controller 650. A first set of signal paths 642, 644, and 646 connect controller 650 and conductor 618. A second set of signal paths 662, 664, and 666 connect controller 650 and conductor 620. The first and second set of signal paths can be used to measure a property of a signal passing through conductors 618 and 620. For example, the first and second signal paths can measure a voltage level between conductors 618 and 620 at various points along the length of conductors 618 and 620. Alternatively, the first and second signal paths can measure an impedance level of conductors 618 and 620 at various points along the length of conductors 618 and 620. Circuit blocks 644 and 664 represent can also be used for performing measurements. In FIG. 6, the circuitry that measures signal properties or cable properties is comprised within controller 650. Alternatively, the measurement circuitry can be a separate and distinct from controller 650 as depicted and described in FIG. 7 below. It is understood that the depicted first and second signal paths are merely exemplary and that other signal paths can be used with other conductors of cable 600 to be able to measure either properties of cable 600 itself or properties of signals passing through cable 600. For example, a non-exhaustive list of signal properties that can be measured include voltage level, current level, power of the signal, frequency components of the signal, attenuation components of the signal, and a degree of skewing of the signal. Similarly, a non-exhaustive exemplary list of cable properties (e.g., properties of conductors of cable 600) that can be measured include impedance, length, operable frequency range, measured degree of crosstalk between set of conductors, electromagnetic interference, and common-mode radiation.

FIG. 7 is a block diagram depicting cable 700 (e.g., a cable) comprising circuitry configured to measure a property

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of a signal passing through cable 700, according to one embodiment. The circuitry can configure cable 700 in a mode of operation where the circuitry can measure a property of signal passing through cable 700 and communicate the measured information with an external device on either the source end or the sink end. The mode of operation is established by turning on/off switches to form a coupling between the circuitry and the conductor similar to the circuitry of FIG. 6 described above. FIG. 7 comprises a measurement circuit (e.g., circuit 760 and its associated signal paths, 772, 774, 776, 782, 784, and 786) that is placed closer to the source end of the cable to be able to measure properties of signals closer to the source end of the cable and communicate to a sink device through a controller (e.g., controller 750).

In FIG. 7, the source end of cable 700 is connected with a connector (not shown) that includes pins, TMDS+ 402, TMDS- 404, CBUS- 406, VBUS 408, and GND 410. The sink end of cable 700 is connected with a connector (not shown) that includes pins, TMDS+ 422, TMDS- 424, CBUS 426, VBUS 428, and GND 430. The pins on the source end and the sink end of cable 600 are the same as the pins of cable 400 described above with reference to FIG. 4. Cable 700 includes a set of conductors (i.e., conductors 712, 714, 716, 718, and 720) between each pin of a connector on the source end and the sink end. Each conductor of the set of conductors is used for transmitting data from the source device to the sink device through the connectors at either end. Cable 700 also includes a circuit that comprises controller 750, switches 732 and 742, and signal paths between controller 750 and one or more of conductors of the set of conductors. Controller 750 is placed closer to the sink end of the cable. For example, controller 750 can be physically placed within a connector on the sink end of the cable. Alternatively, controller 750 can be located within a portion of the cable that includes the conductors but still be located physically closer to the sink end of the cable.

Switch 732 is connected between conductor 716 (connecting CBUS- pin 406 on source end and CBUS pin 426 on sink end) and controller 750. Switch 732 operates in the same way as switch 632 described above in FIG. 6. FIG. 7 also depicts a set of signal paths between controller 750 and conductors 712 and 714. The set of signal paths comprises signal path 790 between controller 750 and circuit 760. Circuit 760 is used for performing measurement of signal properties and can be a separate circuit from controller 750. The set of signal paths also comprises a second set of signal paths and a third set of signal paths. The second set of signal paths 772, 774, and 776 connect circuit 760 and conductor 712. The third set of signal paths 782, 784, and 786 connect circuit 760 and conductor 714. The set of signal paths can be used to measure a property of a signal passing through conductors 712 and 714. For example, the second and third sets of signal paths can measure a skew level of a signal passing through conductors 712 and 714 at various points along the length of conductors 712 and 714. Circuit 760 receives measurement data from the second and third sets of signal paths and processes the received data further before communicating the processed data to controller 750. Circuit 760 is placed closer to the source end of the cable. For example, circuit 760 can be physically placed within a connector on the source end of the cable. Alternatively, circuit 760 can be located within a portion of the cable that includes the conductors but still be located physically closer to the source end of the cable.

Circuit 760 is powered by conductor 718 (power supply voltage via signal 762) and conductor 720 (ground signal via

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signal 764). Controller 750 controls switch 742 to supply voltage to circuit 760 in a first signal mode, where there is no data communication between the source and sink devices. When controller 750 turns off switch 742 using control signal 744 in the first signal mode, circuit 760 receives supply voltage from the sink device through VBUS 428 pin via conductor 718. Circuit 760 receives the ground signal from conductor 720 that is the same ground signal in both signal modes of cable 700. Signals 762 and 764 can include switches in series (not shown) that can provide isolation (i.e., to reduce loading) between circuit 760 and external devices (i.e., source and sink devices) when circuit 760 is not measuring signal properties. Circuit blocks 774 and 784 are also used for performing measurements.

FIG. 8 is a block diagram depicting cable 800 comprising circuitry further comprising a voltage regulator to change supply voltage levels, according to one embodiment. The circuitry can configure cable 800 in a mode of operation where the voltage regulator can change the supply voltage levels between the sink device and the source device of cable 800, and thereby providing a compatible voltage level to both the source device and the sink device.

In FIG. 8, the source end of cable 800 is connected with a connector (not shown) that includes pins, TMDS+ 402, TMDS- 404, VBUS 408, CBUS 406, and GND 410. The sink end of cable 800 is connected with a connector (not shown) that includes pins, TMDS+ 422, TMDS- 424, VBUS 828, CTRL 427, CBUS- 426, and GND 430. The pins on the source end and the sink end of cable 800 are the same as the pins of cable 400 described above with reference to FIG. 4. CTRL pin 427 is an additional pin on the sink side that can be used for communication between controller 850 and sink device. Cable 800 includes a set of conductors (i.e., conductors 812, 814, 816, 818, and 820) between each pin of a connector on the source end and the sink end. Each conductor of the set of conductors is used for transmitting data from the source device to the sink device through the connectors at either end. Cable 800 also includes a circuit that comprises controller 850, switches 832 and 842, and regulator 870.

Regulator 870 is a voltage regulator that can convert voltage level from a first value to a second value. For example, regulator 870 can convert 12V to 5V or from 5V to 12V. Regulator 870 is connected to VBUS pin 428 on the sink end through signal path 874, and is connected to VBUS pin 408 on the source end through signal path 872 and switch 842. Switch 832 is in series with conductor 816 between VBUS pin 408 and VBUS pin 428. Controller 850 controls switches 832 and 842 to force voltage signal passing through conductor between pins VBUS 408 and VBUS 428 (e.g., conductor 816) to pass through regulator 870. For example, when controller 850 turns off switch 832 through control signal 834 and turns on switch 842 through control signal 844, voltage signal from the source end to the sink end (or vice versa) has to pass through regulator 870. In an exemplary embodiment where the sink device is providing 12V on VBUS 428 and when the source device is designed to operate at 5V at VBUS 408, the voltage signal of 12V is passed through regulator 870 to convert to 5V.

Cable 800 also comprises an optional signal path 848 between controller 850 and CTRL pin 427 on the sink end of cable 800. Controller 850 can communicate with the sink device via signal path 848. For example, controller 850 can indicate to the sink device the mode of operation of regulator 870 or even a voltage level at the output of regulator 870 to the sink device. Controller 850 can be controlled by a sink device through CTRL pin 427 similar to controller 550,

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which can be controlled by sink device through signal path **536** as described above with reference to FIG. **5**. In some embodiments, power supply can be provided to controller **850** and to the source device through VBUS **428** pin. Controller **850** can then measure a voltage level at the source end of the cable (e.g., at VBUS pin **406**) and communicate the voltage level to the sink device via signal path **848** and CTRL pin **427**. Accordingly, controller **850** can communicate voltage level (or other cable properties and signal properties) to the sink device via CTRL pin **427** even before conductor **818** forms a connection between CBUS pin **406** and CBUS- pin **426** through a series switch (not shown).

Controller **850** can monitor the input/output voltage of regulator **870** by using a voltage signal (e.g., signal **864**) that can sense a voltage at regulator **870**. Controller **850** generates a control signal **862** that can control the settings of regulator **870**, for example, to set an output voltage of regulator **870**. FIG. **8** depicts that regulator **870** is placed closer to the source end of cable **800** as signified by the broken line symbol on conductor **816**. Alternatively, regulator **870** can be placed closer to the sink end of cable **800**. Controller **850** is powered by a supply voltage signal and a ground signal passing through conductors **816** and **820**, and represented by power signal **852** and ground signal **854**, respectively. Supply voltage signal for controller **850** is connected to the sink end of cable **800** such that even when switch **832** is turned off, controller **850** can still receive supply voltage from the sink device. Alternatively, controller **850** can receive supply voltage from the source end of cable **800** by changing the position of switch **832**.

FIG. **9** is a block diagram depicting a system **900** for connecting a source device **920** and a sink device **930** using two cables **910**, **940**, according to one embodiment. In an embodiment where more than one cable is needed (e.g., due to a length requirement between source device **920** and sink device **930**), cable **910** can be connected between source device **920** and sink device **930** through a second cable, cable **940**. When the second cable does not include internal circuitry (e.g., circuit **216** of FIG. **2**), cable **910** can, in addition to communicating its own properties, communicate the properties of the second cable to source device **920** and/or sink device **930**.

System **900** comprises source device **920**, sink device **930**, cable **940**, and cable **910**. Cable **940** comprises connectors **918a** and **918b**, and cable **910** comprises connectors **914a** and **914b**. Cables **940** and **910** are connected back-to-back in a daisy-chained configuration. Cable **910** further comprises circuit **916** similar to circuit **216** described above with reference to FIG. **2**. That is, circuit **916** can configure cable **910** to communicate data between circuit **916** and either sink device **930** or source device (via interconnect cable **916**).

Cable **940** does not include an internal circuit. Cable **910** with its internal circuitry (circuit **916**) can not only measure properties of itself but also can measure properties of cable **940**. For example, cable **910** can send an electrical signal to cable **940** to determine the length of cable **940**, and in turn communicate the measured data to one of the external devices (source device **920** or sink device **930**) to adjust transmitted signal levels. Similarly, cable **910** can measure properties of signals passing through cable **940**, store the measured data in circuit **916**, and also communicate the measured data to one of the external devices (source device **920** or sink device **930**). In some embodiments, cable **940** can also include internal circuitry similar to circuit **916**.

FIG. **10** is a flowchart depicting a method for communicating data between a source device (e.g., first device **220**)

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and a sink device (e.g., second device **230**) over a cable (e.g., cable **210**), according to one embodiment. The cable, as discussed in FIGS. **4** through **8**, can operate in one of at least two different signal modes of operation to communicate data. In a first signal mode, the cable enables data communication between its internal circuitry (e.g., circuit **216**) and either the source device or the sink device. The first signal mode can be used either to communicate properties of the cable itself or of a signal passing through the cable to either the source device or the sink device. In a second signal mode, the cable enables data communication between the source device and the sink device. The second signal mode can be used to communicate data in accordance with a predetermined protocol (e.g., HDMI and MHL). In an embodiment, the first signal mode is the cable's default mode of operation. Alternatively, the second signal mode is the cable's default mode of operation.

First, the cable communicates **1010** first data in the first signal mode between the circuit of the cable and either a transmitter (e.g., embedded in the source device) or a receiver (e.g., embedded in the sink device). The cable is configured to couple with the transmitter at one end and the receiver at another end via a set of conductors (e.g., conductors **212**) of the cable. The first signal mode is performed when there is no data communication between the source and sink devices in the predetermined protocol. The first data can comprise data related to a measurement of either properties of the cable itself or properties of signals passing through the cable. For example, a non-exhaustive list of signal properties that can be measured include voltage level, current level, power of the signal, frequency components of the signal, attenuation components of the signal, and a degree of skewing of the signal. Similarly, a non-exhaustive exemplary list of cable properties (e.g., properties of conductors) that can be measured include impedance, length, operable frequency range, measured degree of crosstalk between set of conductors, electromagnetic interference, and common-mode radiation.

The cable is then transitioned **1020** from the first signal mode to the second signal mode. The cable can be transitioned, for example, by turning on or off a switch (e.g., switch **432**) coupled to one of the conductors of the cable. As described in FIGS. **4** through **8**, the cable's internal circuit controls the switch to either turn it on or off. In some embodiments, the cable is transitioned from the first signal mode to the second signal mode after the circuit receives an indication from an external device (one of the source or sink devices) that the source and sink devices need to communicate in accordance with the predetermined protocol. Alternatively, the cable transition can occur at a predetermined time interval. After the cable is transitioned into the second signal mode, the cable, in step **1030**, communicates second data between the source and sink devices. In some embodiments where the second signal mode is the cable's default mode of operation, the cable is transitioned from the second signal mode to the first signal mode.

The cable communicates **1030** first data in the first signal mode between the circuit of the cable and either the transmitter or the receiver. The cable can also continuously transition back-and-forth between the default first signal mode and the second signal mode. For example, the cable can operate in a default first signal mode, then transition to the second signal mode, and later transition back to the first signal mode, and so on. In one embodiment, data may be communicated **1010** from the controller to a first external device (e.g., source device) in the default first signal mode and the data may be communicated **1030** from the source

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device to a sink device after the cable is transitioned **1020** from the first signal mode to the second signal mode. The method depicted in FIG. **10** is merely exemplary.

FIG. **11** is a block diagram of either a source device or a sink device that communicates data over a cable, according to one embodiment. In some embodiments, device **1100** comprises an interconnect or bus **1102** (or other communication means) for transmission of data. Device **1100** can include a processing means such as one or more processors **1104** coupled with bus **1102** for processing information. Processors **1104** can comprise one or more physical processors and/or one or more logical processors. While bus **1102** is illustrated as a single interconnect for simplicity, it is understood that bus **1102** can represent multiple different interconnects or buses. Bus **1102** shown in FIG. **11** is an abstraction that represents any one or more separate physical buses, point to point connections, or both connected by appropriate bridges, adapters, controllers and/or the like.

In some embodiments, device **1100** further comprises a random access memory (RAM) or other dynamic storage device depicted as main memory **1112** for storing information and instructions to be executed by processors **1104**. Main memory **1112** can include an active storage of applications including a browser application for using in network browsing activities by a user of device **1100**. Main memory **1112** can further include certain registers or other special purpose memory.

Device **1100** can also comprise a read only memory (ROM) **1116** or other static storage device for storing static information and instructions for processors **1104**. Device **1100** can further include one or more non-volatile memory elements **1118** for the storage of certain elements, including, for example, flash memory, a hard disk, solid-state drive. Device **1100** can comprise transceiver module **1120** that is coupled to bus **1102**. Transceiver module **1120** can further comprise a transmitter module and a receiver module. Transceiver module **1120** comprises one or more ports **1122** to connect to other devices (not shown). For example, device **1100** can function as a source device and connect to another device that can function as a sink device.

Device **1100** can also comprise circuit logic **1140** coupled to bus **1102** and configured to detect information from a second device (not shown) coupled through ports **1122**. The information detected by circuit logic **1140** can include a performance limitation of the second device. Based on the detected information, circuit logic **1140** can configure device **1100** to compensate for the detected performance limitation of the second device and communicate the same to the second device.

Device **1100** can also comprise output display **1126** and coupled via bus **1102**. In some embodiments, display **1126** can include a liquid crystal display (LCD) or any other display technology, for displaying information or content to a user, including three-dimensional (3D) displays. Alternatively, display **1126** can include a touch screen that can also be part of input device **1124**. In some environments, display **1126** can include an audio device, such as a speaker for providing audio information. Device **1100** can also comprise power device **1130** that can comprise a power supply, a battery, a solar cell, a fuel cell, or other device for providing or generating power. Any power provided by power device **1130** can be distributed as required to elements of device **1100**.

While particular embodiments and applications of the present disclosure have been illustrated and described, it is to be understood that the embodiments are not limited to the precise construction and components disclosed herein and

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that various modifications, changes and variations may be made in the arrangement, operation and details of the method and apparatus of the present disclosure disclosed herein without departing from the spirit and scope of the disclosure as defined in the appended claims.

What is claimed is:

1. A method for communicating data between a transmitter of a first device and a receiver of a second device over a cable, the method comprising:

communicating first data in a first signal mode of the cable between a circuit of the cable and either the transmitter or the receiver, the cable configured to couple with the transmitter at one end and with the receiver at another end, and includes a set of conductors, wherein the first data comprises information associated with at least one characteristic of the cable;

transitioning the cable from the first signal mode to a second signal mode by turning on or off a switch of the cable that in the first signal mode couples either the transmitter or the receiver with the circuit through one or more conductors of the set of conductors and in the second signal mode couples the transmitter and the receiver through the set of conductors; and

communicating second data in the second signal mode between the transmitter and the receiver over one or more conductors of the set of conductors.

2. The method of claim 1, further comprising transitioning from the second signal mode to the first signal mode by turning off or on the switch.

3. The method of claim 2, further comprising performing the transitioning from the second signal mode to the first signal mode on a predetermined time interval.

4. The method of claim 2, wherein transitioning the cable from the second signal mode to the first signal mode comprises disconnecting at least one conductor of the set of conductors connecting the transmitter and the receiver.

5. The method of claim 1, wherein the first data includes information derived from a measurement of at least one property of a signal passing through the set of conductors.

6. The method of claim 5, wherein the at least one property of the signal passing through the set of conductors includes at least one of: voltage level, current level, power of the signal, frequency components of the signal, attenuation components of the signal, and a degree of skewing of the signal.

7. The method of claim 1, wherein the at least one characteristic of the cable includes at least one of: impedance, length, operable frequency range, electromagnetic interference, and common-mode radiation.

8. The method of claim 7, further comprising storing the first data in a memory of the circuit during manufacturing of the cable.

9. The method of claim 1, further comprising passing a voltage signal carrying the second data through a voltage regulator to convert a voltage level of the voltage signal from a first level to a second level.

10. The method of claim 1, wherein the switch comprises a plurality of switching elements, and the method further comprises transitioning the plurality of switching elements between a configuration for the first signal mode and a configuration for the second signal mode.

11. A method of operation of a circuit of a cable comprising a set of conductors that extend from one end of the cable configured to couple with a transmitter to another end of the cable configured to couple with a receiver, comprising:

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controlling a switch of the cable, to transition an operation mode of the cable between a first signal mode and a second signal mode,

for the first signal mode, the controlling causing a signal path to be established via the set of conductors to communicate first data between the circuit and either the transmitter or the receiver, wherein the first data comprises information associated with at least one characteristic of the cable, and

for the second signal mode, the controlling causing another signal path to be established via the set of conductors to communicate second data between the transmitter and the receiver.

12. The method of claim **11**, wherein the first data includes information derived from a measurement of at least one property of a signal passing through the set of conductors.

13. The method of claim **12**, wherein the at least one property of the signal passing through the set of conductors includes at least one of: voltage level, current level, power of the signal, frequency components of the signal, attenuation components of the signal, and a degree of skewing of the signal.

14. The method of claim **12**, wherein the at least one characteristic of the cable includes at least one of: impedance, length, operable frequency range, measured degree of crosstalk between the set of conductors, electromagnetic interference, and common-mode radiation.

15. The method of claim **14**, further comprising storing the first data in a memory of the circuit during manufacturing of the cable.

16. The method of claim **12**, further comprising passing a voltage signal carrying the second data through a voltage

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regulator to convert a voltage level of the voltage signal from a first level to a second level.

17. The method of claim **11**, wherein the controlling of the switch comprising controlling a plurality of switching elements of the cable, wherein at least one of the plurality of switching elements is arranged to control whether or not a voltage signal is interrupted between the transmitter and the receiver, and another of the plurality of switching elements is arranged to control whether or not a control signal is interrupted between the transmitter and the receiver.

18. The method of claim **11**, wherein the controlling of the switch comprising causing a high impedance state between the circuit and a control bus conductor of the set of conductors during the second signal mode.

19. A non-transitory computer readable medium having embedded thereon a program, the program being executable by a processor for performing a method for communicating data between a transmitter of a first device and a receiver of a second device over a cable, the method comprising:

communicating first data in a first signal mode of the cable between a circuit of the cable and either the transmitter or the receiver, the cable configured to couple with the transmitter at one end and the receiver at another end via a set of conductors of the cable, wherein the first data comprises information associated with at least one characteristic of the cable;

transitioning the cable from the first signal mode to a second signal mode by turning on or off a switch of the cable; and

communicating second data in the second signal mode between the transmitter and the receiver.

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